

Approved For Release STAT  
2009/08/17 :  
CIA-RDP88-00904R000100100

Dec 1

Approved For Release  
2009/08/17 :  
CIA-RDP88-00904R000100100



**Third United Nations  
International Conference  
on the Peaceful Uses  
of Atomic Energy**

A/CONF.28/P/305

USSR

May 1964

Original: RUSSIAN

Confidential until official release during Conference

**START-UP AND ADJUSTMENT OF REACTOR WWPR OF NOVO-VORONEZH  
ATOMIC POWER STATION**

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The first unit of the Novo-Voronezh atomic power station constructed in accordance with the plan for atomic power development in the Soviet Union is one of the largest experimental and industrial atomic power installations to be commissioned in 1964. The Novo-Voronezh atomic power station is operated by the State Commission for the Utilization of Atomic Energy and is included into the united power grid of the European part of the USSR. The power station furnishes electric power to a huge industrial area in the middle of the European part of the USSR where the organic fuel is short. The commissioning of two units of the power station with water-cooled water-moderated reactors rated at above 550 megawatt will considerably increase the power resources of the area; the cost of electric energy produced by the second unit will be close to the cost of energy generated by conventional power stations located in this area.

At present preparations for the start-up are nearing completion on the 1st unit of the atomic power station. This unit has a water-cooled water-moderated reactor WWPR-1 with a gross power rating of 210 megawatt (Refs.1,2).

This paper gives a brief description of the reactor construction and lay out of the station and summarizes the results of the start-up preparations carried out so far.

25 YEAR RE-REVIEW

In the future the paper will be supplemented with new data which will be obtained in the course of further prestarting adjustment.

The reactor core 3m. dia. and 2.5 m. high is assembled from 349 hexahedral assemblies with an edge size of 144 mm. The assemblies are spaced by 147 mm. 312 assemblies contain operating fuel elements, 37 assemblies are used for reactivity control.

The fuel assembly contains 90 cylindrical fuel elements with an outer diameter of 10.2 mm, arranged in a hexagonal lattice with a 14.3 mm spacing. The fuel elements are filled with tablets of cintered uranium dioxide (Ref.3). The canning of the fuel elements as well as the walls of the assemblies are made from Nb-alloyed zirconium. The central tube of the assembly serving as a structural part in the system which spaces the elements is not filled with tablets.

The reactor is provided with two types of control elements: one to compensate small changes of the reactor reactivity (shim assemblies) and the other to quickly shut down the nuclear reaction (safety assemblies). The shim assemblies consist of two parts. The upper part is an absorber designed as a hexahedral tube with walls which are black to thermal neutrons. In the operating condition the tube is filled with water. The lower part of the shim assembly is almost identical in construction to the fuel assembly. When the shim assembly is placed in the ready-to-operate position the place of the absorber in the core is filled with the fuel.

The safety assembly is likewise comprised of two parts: an absorber and scatterer. The absorber is a cylindrical tube filled with water when in operating condition. The tube is made from an alloy which is black to thermal neutrons. The lower part of the assembly - the scatterer - is made from a zirconium alloy. The safety assembly moves inside a guide tube which is hexahedral on the outside and cylindrical inside. The total number of the control elements is 37; this number includes 6 safety assemblies and 31 shim assemblies. The control elements are uniformly distributed among the fuel elements in the middle portion of the core.

The core is enclosed in a cylindrical vessel with an inner

diameter of 3.8 m. The vessel has a spherical bottom and a detachable flat cover. The cover mounts the actuators of the movable control assemblies. The maximum height of the vessel together with the actuators of the control and safety elements is about 18m.

Coupled to the vessel are 6 circulating loops, each loop consisting of a drum-type steam generator, non-gland circulating pump, four cut-off valves and 500 mm. dia. piping. Each loop together with all auxiliary equipment is arranged in an isolated box. One of the loops is connected to four volume compensators with a total volume of  $70 \text{ m}^3$  using compressed nitrogen. Nitrogen is fed to the volume compensators from compressed gas cylinders; when the pressure in the circuit rises above 115 atm. the nitrogen is discharged through the emergency valves into setting-aside tanks.

Clean water is continuously fed to the circulating circuit of the reactor.  $24 \text{ m}^3$  of this water is fed every hour mainly through the actuators of the control assemblies. The same amount of water is removed from the circuit for purification. The operation of the special purification system depends on the principle of successive self-evaporation. The substances which are insoluble in steam (products of corrosion, non-gaseous fission fragments, etc) accumulate in the evaporator of the last purification stage and are delivered to the burial ground.

The gaseous fission products are discharged into free air through setting-aside tanks and a chimney 120 m high. The purified water is returned to the feed-water system.

The water circulating through the reactor core at a pressure of 100 atm. is heated by  $20^\circ\text{C}$  and fed to the steam generators at a temperature of  $270^\circ\text{C}$ . The drum-type steam generators furnish 1500 t/hr of dry saturated steam at a pressure of 32 atm.

From the steam generators the steam is fed to three turbines each rated at 70 megawatt. The turbines operate on saturated steam; moisture separators placed between the high-pressure and low-pressure cylinders dry the steam fed to the low-pressure cylinder.

The start-up preparations are divided into the following stages:

1. Checking of the quality of installation and acceptance of various systems and assemblies of the station equipment after

installation.

2. Testing, washing and adjustment of various systems and assemblies of the station equipment.

3. Overall testing, adjustment and running-in of the reactor and turbogenerator equipment without nuclear reaction.

4. Loading of the core, physical start-up of the reactor, studying of the reactor physical characteristics.

5. Operation at working parameters, build-up of the station capacity, studying and adjustment of the atomic power station in power operation.

The physical characteristics of the reactor core within a temperature range from 20 to 90°C were mainly investigated on a special test installation. At the end of these investigations - in December 1963 - the core was assembled for test purposes inside the reactor vessel at the power station, which constituted the first stage of the physical start-up. The results of this work are summarized in Ref.4.

When the reactor was loaded with fuel assemblies and when these assemblies were unloaded after physical assembly the fuel reloading system was tested in automatic and semi-automatic operation.

As the core is to be reloaded in the presence of high activity of reloaded assemblies testing and adjustment of the transport facilities is of paramount importance.

The fuel assemblies are brought to the reactor room in special containers, four assemblies per container. On the stocks installed in the room the assemblies are removed from the containers and placed into reloading jackets in the vertical position. The reloading jackets are cylindrical drums open at the top; each drum accommodates 30 assemblies. The assemblies in the drum are spaced apart by the lattice at the top of the drum.

A bridge crane mounted in the reactor room brings the jackets to the stipulated place in the reloading pool. Reloading of the assemblies from the jacket into the reactor is performed by a special reloading bridge. The telescopic rod of the bridge grips the assembly in the jacket, raises it and, after the bridge

and the carriage installed on it have moved (along two coordinate axes in a horizontal plane), sets the assembly into the reactor cell selected by the operator of the reloading bridge.

Unloading of the fuel from the reactor is performed in a similar way in a reverse sequence. At normal operation the assemblies are transported under a layer of water.

During the physical assembly of the reactor core all but two cells of the lattice were loaded; the two cells were reserved for the measuring instruments. In addition to the fuel assemblies the absorbers of the shim assemblies (serving as control elements) as well as the guide tubes and absorbers of the safety assemblies were loaded into the reactor.

From 8 to 15 min. were required to move one assembly from the jacket into the reactor and immerse it into the required cell.

The first loading of the fuel was carried out with a dry reactor. The selected sequence of loading precluded the possibility of formation of local critical volumes should the water accidentally get into the reactor. After loading the reactor was filled with water. By raising some control elements the core was made critical. All operations were carried out with the reactor cover removed.

Monitoring of the core was effected by means of pick-ups installed inside the core and at its periphery. Emergency protection was provided by the standard safety assemblies coupled to electromagnets which could be moved to a height of 2.5 m. in a special truss mounted above the core. In case of emergency the electromagnets are deenergized and the safety assemblies are inserted into the core.

The physical start-up confirmed the design parameters of the cold core and made it possible to find the effectiveness of the safety rods, subcriticality of the reactor in various positions of the absorbers in the core, and other data given in Ref.4.

The attention was paid to the monitoring and safety of overloading. With the core immersed in water overloading of separate assemblies by means of standard overloading devices was simulated.

305

The subcriticality of the core during the overloading was checked with the help of pick-ups placed at the core periphery. Sensitivity of the monitoring instruments to the motion of the assemblies was checked. This made it possible to make recommendations for the standard monitoring system and work out the operating procedure for the replacement of the fuel portion of the shim assemblies which can be removed from the reactor only after the absorber located above the assembly is taken out of the core. It was found that the preliminary removal of two fuel assemblies adjoining the absorber makes the removal of the shim assembly quite safe.

Simultaneously with the preparation and execution of the first stage of the physical start-up and after various systems and assemblies of the equipment were tested and adjusted.

The upper unit of the reactor - the reactor cover - was assembled in the central reactor room. Mounted on the cover were resistance thermometers measuring the temperature of water at the outlet from the core. The actuators of the control and safety systems of the reactor were installed and tested together with the control system. The arrangement of the actuators of the reactor control elements on the cover was such that it was possible simultaneously to perform mounting of these actuators and carry out washing and adjustment of the assemblies in the core circuit. While the mounting operations described above were performed on the cover removed from the reactor a mock-up cover was used to seal the reactor vessel. This mock-up cover had been fabricated earlier for the development of the production techniques in manufacturing the actual cover and for a number of preliminary investigations (determining the mechanical stresses in the cover and in the components of the reactor vessel, testing various methods of sealing the cover, etc.).

After the mounting of the core circuit piping was completed and before work on thermal insulation was started the reactor and the core circuit were hydrolically tested at a pressure of 150 atm. in accordance with the Regulations of the Boiler Supervision Board of the USSR.

During the hydraulic tests the main circulating pumps of

305

the core circuit were tested.

The electrical cricuitry of the station enables the stator winding of the pump motor to be supplied with power either from the generator bus-bars of the station (6000 V, 50 c.p.s.) or from low-frequency motor-generators (600 V, 12.5 c.p.s.) operating from a storage battery. Should the station bus-bars be deenergized the reactor safety system is switched on and the pumps are switched over for low-frequency power supply from the motor-generators included into a so-called fail-safe power supply system. The water flow rate provided by the pumps operating at reduced speed is sufficiently high to cool the core after shutting down the reaction. At the same time the reduced power of the pumps makes it possible to avoid the excessively large capacity of the storage battery.

The pumps were tested at both rotational speeds of the rotor. These tests revealed certain defects in the attachment and suspicion of the pipelines which caused excessive vibration of some assemblies. Subsequently the attachment of the piping was improved and the vibration decreased to the permissible limits.

The preliminary starting of the pumps made it also possible to test and improve the design of temporary filters which are installed in the headers of the steem generators for the duration of the post-installation washing of the core circuit. The location of the filters was changed: they were moved from the outlet to the inlet headers.

After the core circuit has been preliminarily teste changes were made in the construction and attachment of the jackets of the thermocouples which measure the temperature of the coolant in the loops.

The tests of the feed-water system likewise made it possible to reveal and remove a number of defects which causes strong vibration.

Along with testing the equipment of the core circuit adjustments were carried out on the cooling circuit designed for diverting the afterheat of the core following the reactor shutdown and releasing the pressure, on the process water system and on the intermediate circuit which cools the radioactive equipment of the

305



core circuit and prevents contact between this equipment and process water to avoid penetration of radioactivity outside the station.

The electrical part of the station was completely installed and handed over for temporary operation earlier; while the individual systems were being adjusted tests and adjustments were carried out on the electrical equipment, pump motors, motors of remotely controlled devices, interlocking circuits, etc.

About the same time three turbogenerators were tested for no-load operation at the rated speed. The steam necessary for the tests was provided by an auxiliary boiler room using natural gas and by the steam boiler of a railway engine leased specially for the tests.

By May 1964 the mounting and assembly-by-assembly testing of the equipment were completed and the overall testing and running-in of the reactor installation could be started.

One of the most important steps of the adjustment at this stage will be the checking of the core circuit equipment using hot water. The water will be heated with the help of circulating pumps, each pump being rated for 1500 kW. The substandard steam formed in the steam generators will be discharged into a special no-load condenser mounted at the station. These tests will include, among other things, the measurement of stresses appearing in various assemblies of the equipment due to thermal expansion. For this purpose the equipment of two loops and the vessel of the reactor have been equipped with a system of tensometers. The only rigid support for the loop piping is the reactor; the pumps are installed on movable supports (rollers) and the steam generators are suspended by means of steel bands. Thermal expansion of the piping results in the motion of the entire loop equipment. The system designed to compensate for the thermal expansions is also to be checked at this stage of adjustment. During the tests the control elements will be operated and the position indicators of these elements will be checked and adjusted.

All these tests are to take place after the completely assembled cover is installed and sealed on the reactor vessel.

The second stage of the physical start-up will also include

305

determination of differential effectiveness of the control elements when they are moved in definite combinations with different number of absorbers inserted into the core. These experiments will be carried out with the coolant poisoned by boric acid. Simultaneously, the starting positions of various absorber groups will be determined.

Another aim of this stage is to find the temperature coefficient of core reactivity.

When the physical start-up of the reactor is complete the power start-up will be effected and the station will begin generate electric power.

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